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Space and Environmental Science from International Space Station

Paper Presented to the 34th Space Congress

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Abstract

The attached payload sites and the nadir science window on ISS will provide a unique opportunity to perform scientific observations of the earth, space, and the low-earth orbit environment. The high inclination orbit planned for ISS will over fly approximately 75% of the Earth's inhabited surface, giving a unique opportunity to view seasonal and longer term changes in surface conditions, processes and use. In addition, the ISS will provide a platform that will allow studies of atmospheric composition, the condition of the sun, and space environmental effects on materials over long periods of time, with the added benefit of allowing payload return for repair and recalibration. Astronomical observations and surveys from cosmic rays through radio wavelengths will also be possible from ISS. The unique assets of ISS for long term environmental studies are discussed, as well as some planned payloads and investigations which exploit these capabilities.

Introduction

The International Space Station will provide opportunities to study terrestrial and space processes and phenomena, in addition to research in microgravity and life-sciences. Earth-viewing windows and external attachment points for sensors will be added to the Space Station starting in November, 1998, returning the science community to the long-term, observers-in-orbit capability of the Skylab program (1973-74). The International Space Station will provide test capability for sensing devices in a shirt-sleeve environment, and allow software and procedures testing for two-way communication about environmental phenomena.

A trained crew in orbit will refine data-acquisition opportunities in a variety of observational research study areas. Rather than returning huge quantities of data to be screened automatically or visually for significance, humans in orbit can screen observation opportunities and select samples to document. Such observers can also help answer operational questions related to orbital environmental observation and monitoring, such as:

- What kinds of observations are appropriate under rapidly changing conditions?
- How much data should be recorded, processed, transmitted to Earth, or returned physically?
- How many observations need to be made, under how many different conditions?

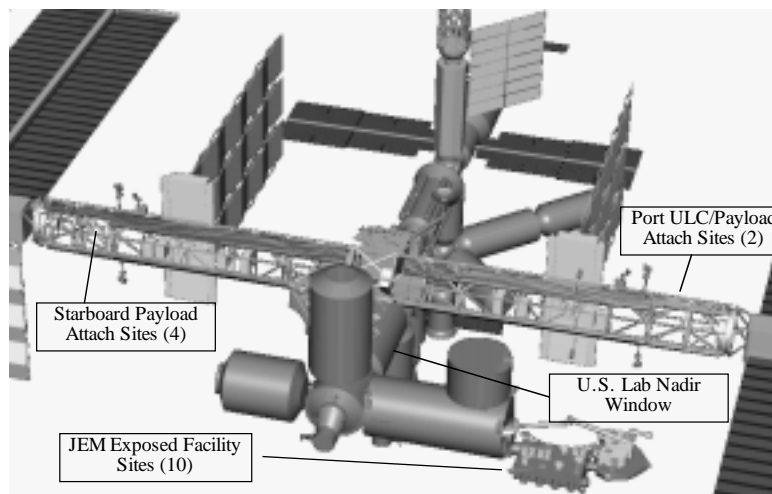
ISS will also provide a platform allowing testing of new sensor packages without the use of an expendable launch vehicle, with the capability of returning the sensor package to Earth for repair, refurbishment or redesign.

The ISS flies in a fixed attitude with respect to Earth much like an airplane, with the long axis of the U.S. Laboratory parallel to the velocity vector direction and the Japanese and ESA modules, and the truss, parallel with the surface of the Earth and perpendicular to the velocity vector (like airplane wings). This provides a stable, oriented platform with only a few degrees of deviation due to variations in aerodynamic torques from atmospheric drag. The orbital inclination is 51.6 degrees and the altitude varies from about 330 to 460 km (180 to 250 nautical miles) due to orbital decay and reboost thruster firings.

Accommodations

There are several locations on the ISS from which Space and Environmental science can be performed. Figure 1 shows these locations and each is described below. The first attached science payloads will be launched on the fourth utilization flight, UF-4, in January 2001, with another set of experiments to be launched a few months later on UF-5. These payloads will occupy the truss-mounted payload attach sites on S3. The first Japanese Exposed Facility payloads will be deployed in 2003.

Figure 1. ISS Accommodations for Earth and Space Science Payloads



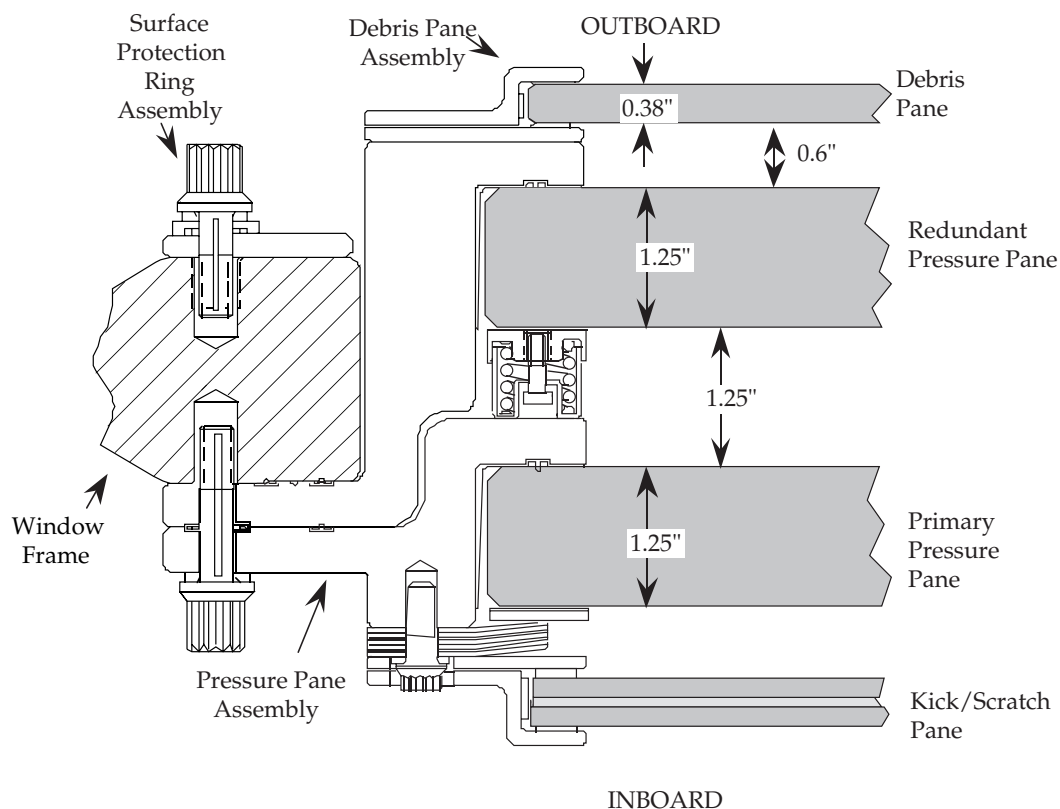
U.S. Laboratory Nadir Research Window

The United States Laboratory Module will contain a high optical performance nadir viewing window. It will be 56 cm in diameter, with 51 cm of clear aperture, and consist of three panes of fused silica that have spectral transmittance from the UV through the reflected solar infrared (Fig. 2). The pane exposed to the space environment, the debris pane, is designed to absorb orbital debris impacts that would otherwise damage the redundant pressure pane. It can be removed for refurbishment if impact pitting degrades window performance over time. When the window is not in

use, an external cover (not shown on Fig. 2) can be rotated into place to protect the window. The inboard kick/scratch pane provides a protective UV coating which may inhibit sensor deployment; accordingly, it will be removed for window observing runs. When the window is not in use, and external cover (not shown in Fig. 2) can be rotated into place to protect the window. This window will have a wave front error of $\approx 1/7\lambda$, which will greatly enhance the Earth observations capability of the ISS over the Space Shuttle Orbiter.

Appropriate mounting hardware for sensors, and full Space Station utilities will be available at the window workstation. Plans are in development for this facility are underway. At present, upmass and volume constraints will prohibit placing a fully capable work station early in the program. However, a rack that will provide capability for single payloads is under development, and will be flown no later than UF-2. This early facility will provide stable mounting for individual instruments, and will allow access to Station power and data utilities as well as storage for cameras, sensors and the kick-scratch pane when it is not in place. As the program matures, it is expected that capability of the Window facility (presently named the Window Observational Research Facility, or WORF) will increase to include 1) access Global Positioning System (GPS) information as applies to targeted payloads; 2) autonomous pointing and motion compensation of payloads, incorporating GPS information, and 3) increased data storage.

Figure 2. ISS Nadir Window and Window Mount Configuration



Truss Payload Attach Sites

There are 4 payload attach sites on the starboard truss segment 3 (S3). Two are on the zenith side of the truss providing viewing of space as well as in the ram (velocity vector) and wake directions and two are on the nadir side providing viewing toward the Earth along with ram and wake.

The mounting mechanism for attached payloads is known as the Payload Attach System. It is a robotically compatible system with remotely operated mechanical, power and data connectors. The resources available at each site are described in Table 1. These provide adequate power and data for a wide variety of large science payloads.

Table 1. Payload Attach Site Resources

There are also two sites on the port side of ISS (P3 truss segment) which have interfaces and utilities identical to those on the S3 sites. These are primarily to be used for logistics carriers to bring new equipment and supplies to ISS, but can be used as payload sites on a non-interference basis.

EXPRESS Pallet

The EXPRESS Pallet is being developed to provide multiple payload users with a simple, standard interface to the exterior of ISS (Fig. 3). EXPRESS stands for *EX*pedite the *PR*ocessing of *E*xperiments to *S*pace *S*tation. The simple interface, and the streamlined documentation and payload integration process, will reduce the cost and the amount of time it takes to get a payload onto ISS. Each Pallet provides up to 6 payloads with the resources given in Table 2. EXPRESS Pallets will be ideal for the smaller payloads typically flown on satellites, with the added advantages of the large, stable platform and the potential for crew repair or experiment retrieval for refurbishment or recalibration.

Table 2. EXPRESS Pallet Resources

Japanese Experiment Module - Exposed Facility

The Japanese Experiment Module has a “back porch” called the JEM Exposed Facility (JEM-EF). The JEM-EF can accommodate up to 10 operating, phone booth-sized payloads and has locations for 2 more spare or passive experiments. The JEM also has an airlock and remote manipulator system (robot arm) which will allow interaction of the crew with the experiments on the EF. For instance, a sample from one of the payloads can be retrieved using the robot arm and then passed to the crew for analysis via the airlock. The resources available are listed in Table 3.

Figure 3. EXPRESS Pallet

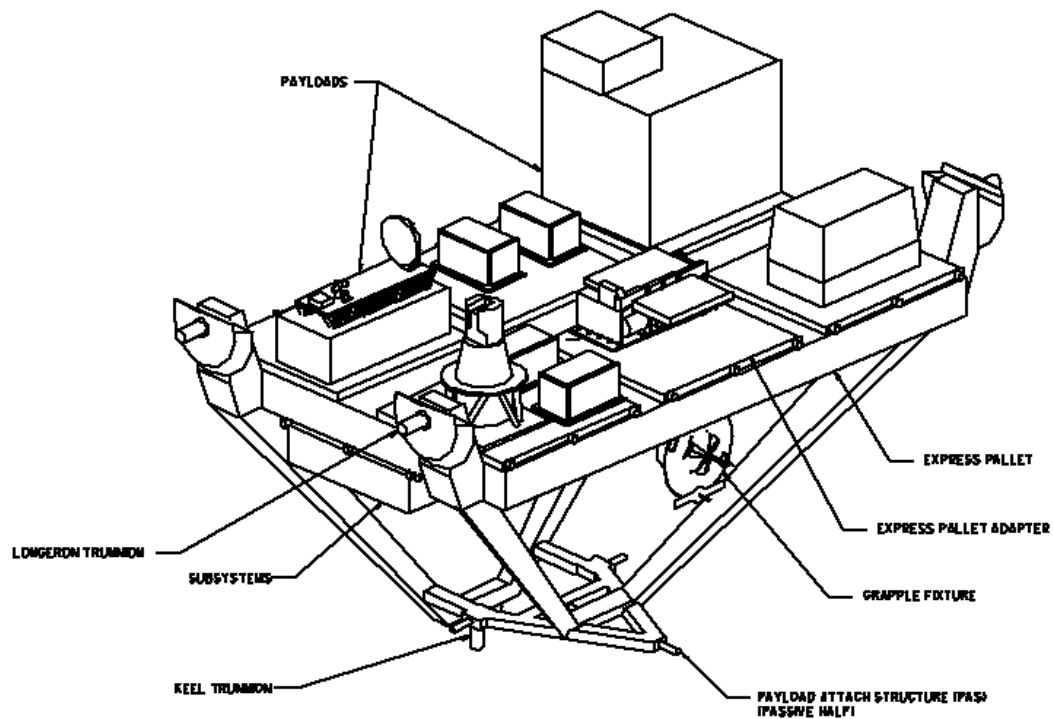


Table 3. JEM-EF Resources

Proposed Science

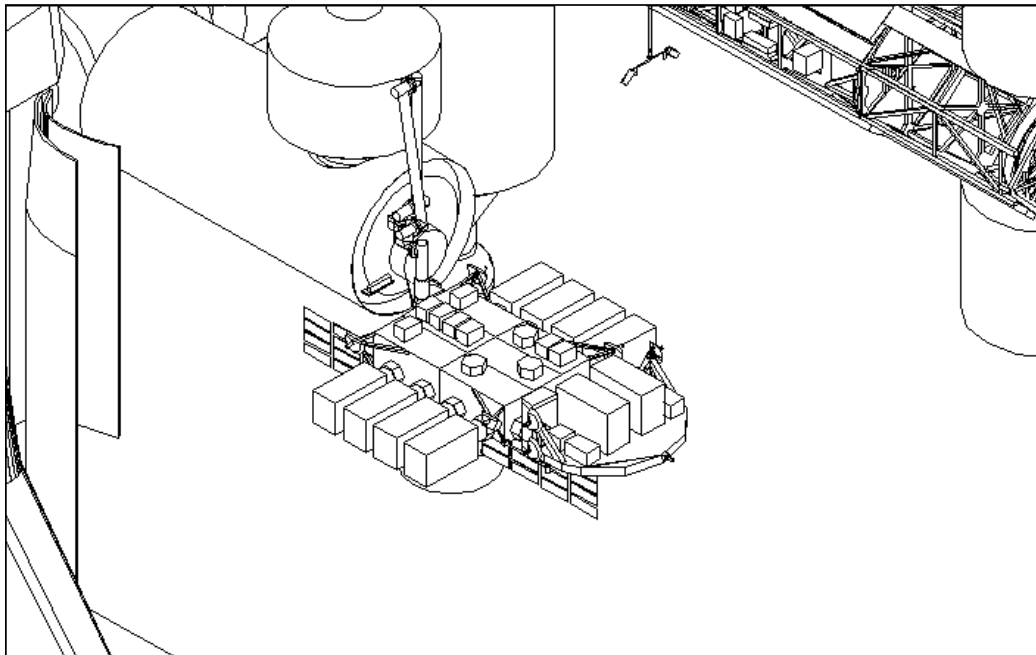
Several payloads have already been approved for deployment on ISS and many others have expressed interest. Inclusion of a particular payload in the following discussion does not imply approval. These are discussed to give a flavor of the type of science possible from ISS.

Alpha Magnetic Spectrometer (AMS)

AMS is a large payload designed to determine the composition of the cosmic ray environment. Of particular interest are anti-protons, which may provide insight into the composition of dark matter, and anti-helium nuclei, which are important to understanding whether the universe is symmetric (composed of equal quantities of matter and anti-matter) or not. The payload consists of a 1.5 kg

permanent magnet, silicon detectors for tracking particle trajectories through the magnet, and detectors for measuring velocity to determine mass of the particles. AMS will occupy one of the four S3 attach sites. AMS will fly a precursor mission on Shuttle mission STS-91 to try out the instrument.

Figure 5. Japanese Experiment Module - Exposed Facility



Stratospheric Aerosol and Gas Experiment (SAGE-III)

SAGE-III is the descendant of a long line of experiments which have been measuring stratospheric aerosols and later ozone chemistry constituents since the Apollo-Soyuz mission in the mid-70s. It is a relatively small EXPRESS Pallet-based instrument which observes the rising and setting of the sun and moon through the Earth's atmosphere in order to determine the structure and composition of the atmosphere. SAGE and its predecessors have been critical in the understanding of ozone depletion chemistry.

Issues and Constraints

External Contamination

One of the major concerns with the operation of remote sensing instruments on ISS has been the external contamination environment. It would seem that a large, complex, permanently manned vehicle would not be an inviting platform from which to make sensitive optical measurements.

However, the Space Shuttle has shown that unique and important astronomical and Earth observations can be made from a manned vehicle. The requirement levels are actually quite stringent for ISS and the hardware developers have worked very hard to meet these requirements. Although ISS may not be an ideal platform for cryogenically cooled infrared instruments due to deposition of contaminants on the extremely cold surfaces, these requirements are compatible with a wide range of remote sensing applications making ISS, with its unique orbit, resource, and human-tended capability a highly desirable platform. The external contamination requirements are summarized below. The quiescent state is the steady-state, long-term condition, while non-quiescent refers to time periods when the Shuttle or other transfer vehicle is approaching or docked, reboost thruster burns, or occasional venting and dumping.

Table 4. Standards for Induced External Environment

Payload Pointing and ISS Positioning and Pointing Accuracy

ISS will be a large vehicle, with many joints and couplings that will flex under thermal loads and differential acceleration. Although the ISS will be providing GPS information, the GPS antennas will be located at the S0 truss site, and so will record the location and attitude of that location only. Although a coarse positioning of the window and the external attach points can be calculated from the S0 location on the basis of the Station geometry, it is not known how large the error bars on that calculation will be as a result of Station flexing and torquing. A number of payloads may need to deploy star trackers or separate GPS receivers to improve on the location accuracy of the truss attach points and window plane, so as to ensure that sensors are pointed in the direction desired and at the target of interest.

EXPRESS Pallet Adapter Payload Interaction

One potential issue that will develop with EXPRESS pallet payloads will be the potential for payload interference, particularly with regards look direction and angle. A good example of this potential conflict is the SAGE III payload, which needs to look at the Earth's limb in both the ram and wake direction. This will constrain adjacent payloads to remain at or below the limit of the SAGE III look envelope. Analyses of the potential interference of adjacent payloads will be necessary whenever an EXPRESS pallet is prepared for flight.

Conclusions

Although the International Space Station is best known for the laboratory environment it will provide for life sciences and microgravity research, its high orbital inclination and stable platform will make it ideal for Earth and space observational research. The combination of external attach point and high optical performance window will provide a variety of accommodations for researchers to monitor the Earth's environment, conduct astronomical observations, and test and prove out new sensor packages. In particular, the ability to return sensor packages home after extensive periods of time on orbit will allow sensors to be calibrated or upgraded without the loss of the original package, as is common on expendable spacecraft. With the completion of ISS, a new era in Earth and space observational sciences will begin that will likely change the standard concept of how these kinds of research are done in space.